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Original Article

Associations between specific technologies and adolescent sleep quantity, sleep quality, and parasomnias

Teresa Arora [a,b], Emma Broglia [c], G. Neil Thomas [d,e], Shahrad Taheri [a,b,*]

[a] Weill Cornell Medical College in New York, USA
[b] Weill Cornell Medical College in Doha, Qatar
[c] School of Psychology, University of Birmingham, United Kingdom
[d] Unit of Public Health, Epidemiology and Biostatistics, School of Health and Population Sciences, University of Birmingham, United Kingdom
[e] Institute of Public Health, Social and Preventive Medicine, Mannheim Medical Faculty, Heidelberg University, Mannheim, Germany

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A B S T R A C T

Objective: We tested the hypothesis that weekday bedtime use of six technologies would be significantly associated with eight sleep parameters studied relating to sleep quantity, sleep quality, and parasomnias.
Methods: In our cross-sectional study, we previously administered validated age-appropriate questionnaires (School Sleep Habits Survey, Technology Use Questionnaire). Participating adolescents ($n = 738$; 54.5% boys) were aged 11–13 years and were from the Midlands region of the United Kingdom in 2010.
Results: Frequent use of all technology types was significantly inversely associated with weekday sleep duration (hours). Frequent music listeners and video gamers had significantly prolonged sleep onset ($\beta = 7.03$ [standard error {SE}, 2.66]; $P < .01$ and $\beta = 6.17$ [SE, 2.42]; $P < .05$, respectively). Frequent early awakening was significantly associated with frequent use of all technology types. The greatest effect was observed in frequent television viewers (odds ratio [OR], 4.05 [95% confidence interval {CI}, 2.06–7.98]). Difficulty falling asleep was significantly associated with frequent mobile telephone use, video gaming, and social networking, with music listeners demonstrating the greatest effect (OR, 2.85 [95%CI, 1.58–5.13]). Music listeners were at increased risk for frequent nightmares (OR, 2.02 [95%CI, 1.22–3.45]). Frequent use of all technologies except for music and mobile telephones was significantly associated with greater cognitive difficulty in shutting off. Frequent television viewers were almost four times more likely to report higher sleepwalking frequency (OR, 3.70 [95% CI, 1.89–7.27]).
Conclusions: Frequent weekday technology use at bedtime was associated with significant adverse effects on multiple sleep parameters. If confirmed in other samples and longitudinally, improving sleep hygiene through better management of technology could enhance the health and well-being of adolescent populations.

1. Introduction

The impact of sleep duration and sleep difficulties on health and performance is increasingly recognized [1,2]. Adolescence is associated with circadian phase alterations, which conflicts with social demands; thus this important developmental period is commonly accompanied by sleep deprivation [3]. Sleep problems also are frequently reported in adolescence and can be categorized into insomnia (difficulties initiating and maintaining sleep) [4], daytime sleepiness [5], parasomnias (sleep terrors, sleepwalking, bruxism, and nightmares) [6], and movement disorders (e.g., restless legs syndrome) [7].

Ownership and use of multiple technology devices is increasing and is prevalent in the adolescent population [8]. Calamaro et al. [9] showed that children ages 6–10 years with three technology types in their bedroom achieved 45 min less sleep than those without. Although there are multiple benefits from modern technology, its use may promote and exacerbate adolescent sleep deprivation. Television viewing [10], video gaming [11], computer use [11], and mobile telephone use [12] have been associated with reduced sleep duration or sleep disturbance. However, little is known about the effects of social networking on sleep, especially in young adolescents who commonly engage in this form of electronic communication with peers. Shorter sleep duration, also associated with daytime sleepiness, has been linked with negative consequences for health and performance such as obesity [13] and lower school grades [2,14].

* Corresponding author. Address: Weill Cornell Medical College in Qatar, Qatar Foundation – Education City, PO Box 24144, Doha, Qatar. Tel.: +974 4492 8998; fax: +974 4492 8970.
E-mail address: staheri@me.com (S. Taheri).

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The impact of technology use on sleep parameters aside from sleep duration, including sleep-onset latency (SOL), sleep difficulties, nighttime awakenings, and parasomnias also may be important. Munezawa et al. [6] demonstrated that mobile telephone use after lights out was significantly associated with sleep disturbances, including short sleep duration, reduced sleep quality, excessive daytime sleepiness, as well as symptoms of insomnia in a large sample of Japanese adolescents aged 13–18 years. King et al. [15] experimentally showed a decrease in objective sleep efficiency, total sleep time, and rapid eye movement sleep along with an increased subjective SOL in adolescents (mean age, 16 years). To date, no studies have examined the impact of specific technologies on multiple sleep parameters in a young adolescent sample. Therefore, we sought to examine these relationships in a large early adolescent cohort.

2. Methods

2.1. Study population

Seven schools were randomly selected and recruited into the Midlands Adolescents Schools Sleep Education Study. Parents of registered students were mailed a letter regarding study participation. Student participants were included if they (1) provided parental consent, (2) provided personal written consent, (3) were not previously diagnosed with a sleep disorder, (4) were not taking sleep medication, or (5) had not traveled to a different time zone 4 weeks prior to data collection. A total of 1495 parents of year 7 and year 8 students were contacted across participating schools. The overall parental response rate was 79% ($n = 1181$). A total of 1075 (91%) participants' parents provided parental consents. Of those eligible, a sample of 959 (89%) provided data used for subsequent analyses. There were no statistically significant differences between participating and nonparticipating students for age, gender, or ethnicity ($P > .05$). All participants were aged between 11 and 13 years and were registered in education in the United Kingdom. The type of school (secondary [57.8% of sample], grammar [37.5% of sample], and independent [4.7% of sample]) was used as a potential proxy for socioeconomic status [16]. Self-reported data included ethnicity (42.9% white, 41.8% Asian, 5.1% black, 4.2% mixed race, and 6.0% other); gender (54% boys); bedroom sharing (69.5% nonsharing); napping (54%); extracurricular sporting activity (55%); paid employment (4%); self-reported ownership of a mobile telephone (88.7%) and portable game console (82.7%); and the presence of television (54.7%), video game console (44.7%), computer or laptop (58.5%), or music player (74.5%) in the participants' bedrooms.

2.2. Exposure and outcome measures

Participants completed an online survey including the previously validated School Sleep Habits Survey (SSHS) [17] and the Technology Use Questionnaire [18]. All measures were self-reported; information was obtained on weekday sleep duration (h) and SOL (min). The number of nighttime awakenings was categorized (never/once per night/two or more times per night/do not know). We also asked about difficulty falling sleep in previous 2 weeks (never/once/twice/several times every day or night). Additionally, we included questions about sleepwalking (never/once/twice/several times every day or night) and bad dreams or nightmares (never/once/twice/several times every day or night). The SSHS provided information on waking early with the inability to fall back to sleep termed *early awakening* (never/once/twice/several times every day or night). Difficulty falling asleep at bedtime (Likert scale 0–10; 0 = no difficulty and 10 = great difficulty) provided an indication of how difficult participants reported switching off their minds for sleep initiation. A median split was calculated for difficulty switching off at bedtime and was dichotomized into no ($\leqslant 3$ points) or yes (>3 points) to perform the logistic regression analysis.

We specifically assessed weekday sleep duration as sleep reduction is more likely to occur due to school attendance, and sleep loss throughout the week may exhibit stronger effects compared to weekends when sleep debt may be partially repaid. Technology use (television viewing/video games/computer or laptop for studying/Internet for social networking/mobile telephone for calling or texting/music) before going to bed on weekdays was obtained (never, sometimes, usually, or always). We also calculated the amount of technology within the bedroom (0–6 technologies). Ethical approval was obtained from the University of Birmingham Research Ethics Committee (ERN_08-437).

2.3. Other measures

We obtained objective measures of height (to nearest 0.5 cm) and weight (to nearest 0.1 kg) for calculation of body mass index (BMI) converted into BMI *z* scores. Information was obtained from the SSHS on circadian preference (definitely morning/more morning than evening; or more evening than morning/definitely evening); bedroom sharing (yes/no); sleeping with lights on (yes/no), bedtime caffeine consumption (never/sometimes/usually/always), napping (yes/no) and extracurricular sporting activities (yes/no). Participants also reported age, gender, school, and ethnicity. Information on these additional factors was obtained to rule out potential confounders and to better isolate the impact of technology use on adolescent sleep.

2.4. Statistical analysis

Data analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 20.0 Chicago, IL, USA). We assessed if the quantity of bedroom technology (0–6) was related to each of the sleep parameters using Pearson bivariate correlation, independent *t* tests, or analysis of variance as appropriate. We conducted an independent *t* test to assess if SOL was related to circadian preference. We then assessed if early weekday wake time (06:30 AM or earlier) was related to circadian preference using χ^2 testing.

To assess the relationships between all types of technology and sleep duration and SOL, we first conducted analysis of variance. Linear regression was then conducted to assess the relationships between all technology types and sleep duration (h) in addition to SOL (min) while considering a range of potential confounders. Relationships between each type of technology and categorical sleep parameters also were explored using multinomial regression techniques or multiple logistic regression analyses as appropriate. All models were adjusted for gender, school, ethnicity, caffeine consumption, circadian preference, BMI *z* score, sleeping with lights on, and bedroom sharing. Models that reached statistical significance after adjustment are presented according to technology type and sleep parameter.

3. Results

Of the 959 student volunteers who provided data, 738 (77%) had complete information on all variables of interest. There was a negative correlation between the quantity of bedroom technology and sleep duration ($r = 0.15$; $P < .001$). No relationships were observed for quantity of bedroom technology with any other sleep parameters. Although those with an evening circadian preference ($n = 459$) had a slightly longer mean SOL (28 min) compared to

those with a morning circadian preference (26 min), this difference was not statistically significant ($P = .43$). Of those who reported waking at 06:30 AM or earlier on weekdays ($n = 168$), 56.5% reported morning circadian preference compared to 32.3% who reported waking later than 06:30 AM on weekdays ($\chi^2 = 32.94$, [$n = 2$]; $P < .001$). Table 1 shows the means ± standard deviations for sleep duration (h) and SOL (min) by each technology type. For those who usually/always used any type of technology, weekday sleep duration was significantly shorter than those who either sometimes/never used the technology ($P < .05$). SOL was significantly longer in those who usually/always listened to music compared to those who never/sometimes listened ($P = .001$). Table 2 shows that greatest negative effects on sleep duration (h) were in those who usually/always used the Internet for social networking or mobile telephones before bedtime after adjustment ($P < .001$). A high frequency (usually/always) of video gaming ($P < .05$) and music listening ($P < .01$) was associated with significantly longer SOL after adjustment.

The odds ratios and 95% confidence intervals for logistic regression models are presented in Tables 3 and 4. The highest frequency of early awakening episodes was significantly associated with greater frequency (usually/always) for all six technology types before bedtime. Greatest effects were observed in television viewers, music listeners, and social networkers ($P < .05$).

Those who reported usually/always playing video games, listening to music, or using the Internet for social networking before bedtime showed greatest increased risk for difficulty falling to sleep (several times/every night) ($P < .05$). Interestingly, more frequent nightmares were significantly associated with music listening only ($P < .05$).

After adjustment, those who usually/always watched television at bedtime, used a computer or laptop to study, used the Internet for social networking, or played video games had a significantly increased risk for difficulty switching off ($P < .05$). Sleepwalking was significantly associated with watching television, playing video games, and using a computer or laptop for studying ($P < .05$).

4. Discussion

4.1. Sleep quantity

Although our findings have shown a significant reduction in weekday sleep duration for bedtime use of all technologies assessed, the greatest impact was observed with frequent users of social networking sites who reported almost 1-h less sleep. These findings are consistent with a recent study reporting that 37% of 268 young adolescents lost sleep on ⩾1 occasion due to social networking [19]. Our data also show that computer use for studying had a negative impact on weekday sleep duration, which is in line with findings from a large sample of children ages 4–13 years [20]. However, it should be noted that computers and other devices have multiple uses, sometimes overlapping with other technologies or allowing multiple tasks to be simultaneously undertaken. Our study refined computer use for the purpose of studying or homework only and treated the Internet separately, ensuring that potential overlap was stratified.

Experimental studies that have assessed acute effects of video gaming on adolescent sleep are inconsistent. One study found no effect of violent video gaming on subjective sleep measures [21]. More recently, prolonged violent video gaming was associated with a 27-min reduction in polysomnographic sleep duration and a 17-min increased subjective SOL compared to regular gaming [22]. Although we did not examine video game content, our findings demonstrated that frequent bedtime video gaming was significantly associated with decreased sleep duration and increased SOL.

Similar to others who have shown reduced time in bed [23] and increased tiredness [24] among adolescent mobile telephone users, we observed significant reductions in weekday sleep duration with bedtime mobile telephone use. Although previous data have shown prolonged SOL with longer television viewing and video gaming [25], adolescent bedtime use of mobile telephones has not yet been investigated in relation to weekday SOL. We found no evidence of delayed SOL with mobile telephone use.

Table 1
The relationships between sleep duration (h) and sleep-onset latency (min) and six technologies assessed in 738 UK adolescents.

	n (%)	Sleep duration (h)	*F* (*P* value)	Sleep-onset latency (min)	*F* (*P* value)
Television					
Never	359 (48.6)	8.83 ± 1.16	4.925 (.008)	28.05 ± 26.15	0.432 (.650)
Sometimes	232 (31.4)	8.81 ± 1.45		25.96 ± 27.29	
Usually/always	147 (20.0)	8.45 ± 1.37		27.76 ± 30.57	
Video gaming					
Never	425 (57.6)	8.91 ± 1.20	8.067 (<.001)	25.99 ± 24.07	2.571 (.077)
Sometimes	189 (25.6)	8.60 ± 1.31		31.23 ± 34.39	
Usually/always	124 (16.8)	8.44 ± 1.55		26.02 ± 25.85	
Mobile telephone					
Never	298 (40.4)	9.05 ± 1.26	19.869 (<.001)	27.84 ± 26.56	1.087 (.338)
Sometimes	230 (31.2)	8.74 ± 1.30		25.23 ± 27.37	
Usually/always	210 (28.4)	8.33 ± 1.27		28.93 ± 28.62	
Music					
Never	291 (39.5)	8.87 ± 1.28	4.759 (.009)	26.57 ± 24.96	6.739 (.001)
Sometimes	283 (38.3)	8.78 ± 1.19		24.29 ± 23.97	
Usually/always	164 (22.2)	8.49 ± 1.51		33.95 ± 35.15	
Computer or laptop (study)					
Never	387 (52.5)	8.90 ± 1.30	7.446 (.001)	28.62 ± 28.82	1.375 (.254)
Sometimes	232 (31.4)	8.69 ± 1.24		26.94 ± 27.30	
Usually/always	119 (16.1)	8.39 ± 1.37		23.92 ± 22.38	
Internet (social)					
Never	378 (51.2)	9.03 ± 1.23	29.652 (<.001)	27.51 ± 27.12	0.184(.832)
Sometimes	168 (22.8)	8.78 ± 1.27		26.25 ± 29.51	
Usually/always	192 (26.0)	8.17 ± 1.31		27.93 ± 26.18	

Data are presented as mean ± standard deviation.
F statistic and *P* values were obtained through analysis of variance.

Table 2
The linear regression relationships between specific weekday technologies at bedtime, weekday sleep duration (h), and weekday sleep-onset latency (min) in 738 UK adolescents.

	Model 1 β (SE)	Model 2 β (SE)
Weekday sleep duration (h)		
Television viewing		
Sometimes	−0.02 (0.11)	−0.00 (0.11)
Usually/always	−0.38 (0.13)**	−0.34 (0.13)**
Video gaming		
Sometimes	−0.31 (0.11)**	−0.32 (0.12)**
Usually/always	−0.47 (0.13)***	−0.47 (0.14)**
Mobile telephones		
Sometimes	−0.31 (0.11)**	−0.33 (0.12)**
Usually/always	−0.72 (0.12)***	−0.75 (0.12)***
Music		
Sometimes	−0.10 (0.11)	−0.08 (0.11)
Usually/always	−0.39 (0.13)**	−0.35 (0.13)**
Computer or laptop (study)		
Sometimes	−0.21 (0.11)	−0.18 (0.11)
Usually	−0.51 (0.14)***	−0.45 (0.14)**
Internet (social)		
Sometimes	−0.25 (0.12)*	−0.25 (0.12)*
Usually/always	−0.86 (0.11)***	−0.86 (0.12)***
Weekday sleep-onset latency (min)		
Music		
Sometimes	−2.28 (2.27)	−2.84 (2.27)
Usually/always	7.38 (2.66)**	7.03 (2.66)**
Video gaming		
Sometimes	0.04 (2.79)	2.81 (2.95)
Usually/always	5.24 (2.39)*	6.17 (2.42)*

Abbreviations: SE, standard error; h, hours; min, minutes.
Model 1: unadjusted.
Model 2: adjusted for gender, school, ethnicity, circadian preference, caffeine consumption, body mass index *z* score, lights on in room while sleeping, bedroom sharing, and napping.
Data are presented as unstandardized β coefficients (standard error).
The reference category was never. Dummy variables were created to examine frequency of technology type.
* $P < .05$.
** $P < .01$.
*** $P < .001$.

Early evidence from a large study comprising 11 European countries found that excessive television viewing was associated with later bedtimes [26]. Televisions and other electronic devices are increasingly located in adolescent bedrooms [27], and the presence of a bedroom television set has been associated with reduced adolescent sleep duration [28]. Our findings suggest that frequent bedtime television viewing may significantly reduce sleep duration by approximately 20 min compared to those who do not engage in this activity. Although another group found a relationship between long duration of television viewing and prolonged SOL [25], we did not confirm this finding in our study.

Data investigating potential links between adolescent sleep duration and listening to music are limited. A previous study suggested that music was considered as a sleep aid in adolescents [29]. However, our findings demonstrated that music listening at bedtime was associated with a significant reduction (0.35 h) in weekday sleep duration after adjustment. Furthermore, our data show that frequent music listeners may significantly prolong sleep onset by 7 min. For some individuals music listening is incorporated into bedtime routines. The effect of relaxing music styles on sleep has previously been explored in older adults [30]. Although our study did not ascertain information on music genres, our findings suggest the music may be mentally or physically stimulating, with potential negative effects on sleep.

4.2. Sleep difficulties

Although significant prolonged SOL was only observed in video gamers and music listeners, we also explored if our sample reported difficulty falling sleep or difficulty shutting off their minds when attempting sleep. All six technologies were associated across these two sleep parameters. Frequent video gamers, social networkers, television viewers, and computer users had a significantly increased risk for difficulty shutting off their minds. Television viewing has been previously linked with more difficulty initiating sleep and reduced sleep duration [26]. However, difficulty in cognitively shutting off when attempting to sleep has not been previously investigated in relation to adolescent bedtime technology use, with the exception of presleep video gaming in which Weaver et al. [31] reported increased cognitive alertness during use of this technology. It is possible that visual content exposure or cognitive processes (decision-making, problem-solving, memory) occurring from engaging with electronic devices increase this sleep parameter.

Frequent video gamers, social networkers, music listeners, and mobile telephone users reported an increased risk for difficulty falling asleep. Although music listening may be passive, it was associated with increased difficulty falling to sleep and prolonged SOL in our study, potentially through the music content or genre. It is possible that multiple technologies were being used while listening to music (i.e., social networking, Internet browsing, texting), which Calamaro et al. [32] have previously shown through development of a multitasking index. However, other technologies associated with increased difficulty falling sleep may be more interactive or may require more thought. This action may prolong cognitions and thought processes in relation to the observed content or communication from the device and thus produce a lagged effect, thereby perpetuating difficulty initiating sleep.

Table 3
The odds ratios and 95% confidence intervals for the multinomial regression between specific technologies and sleep parameters in 738 UK adolescents.

Early awakening, *n* (%)	Television viewing		Mobile telephone	
	Sometimes	Usually/always	Sometimes	Usually/always
Once, 199 (27.0)	1.65* (1.10–2.48)	1.29 (0.79–2.12)	0.76 (0.50–1.15)	1.17 (0.76–1.81)
Twice, 75 (10.2)	1.64 (0.91–2.95)	1.26 (0.62–2.57)	1.46 (0.78–2.72)	2.11* (1.10–4.03)
Several times every night, 75 (10.2)	2.90* (1.52–5.52)	4.05* (2.06–7.98)	1.18 (0.61–2.32)	2.92* (1.56–5.47)
Early awakening	**Music**		**Internet (social)**	
	Sometimes	Usually/always	Sometimes	Usually/always
Once, 199 (27.0)	1.23 (0.83–1.82)	1.48 (0.92–2.37)	0.81 (0.52–1.26)	0.96 (0.62–1.50)
Twice, 75 (10.2)	2.09* (1.13–3.87)	3.09* (1.58–6.08)	0.99 (0.50–1.96)	2.34* (1.30–4.21)
Several times every night, 75 (10.2)	1.78 (0.95–3.34)	3.43* (1.77–6.66)	1.79 (0.92–3.49)	3.50* (1.91–6.42)
Early awakening	**Video gaming**		**Computer or laptop (study)**	
	Sometimes	Usually/always	Sometimes	Usually/always
Once, 199 (27.0)	1.18 (0.78–1.79)	0.98 (0.57–1.67)	1.16 (0.78–1.72)	1.05 (0.63–1.76)
Twice, 75 (10.2)	1.39 (0.76–2.53)	1.50 (0.71–3.16)	2.00* (1.15–3.50)	1.21 (0.56–2.62)
Several times every night, 75 (10.2)	1.45 (0.77–2.70)	2.72* (1.39–5.34)	1.24 (0.68–2.24)	1.99* (1.02–3.88)
Difficulty falling to sleep	**Television viewing**		**Mobile telephone**	
	Sometimes	Usually/always	Sometimes	Usually/always
Once, 188 (25.5)	0.67 (0.44–1.03)	0.86 (0.52–1.42)	0.90 (0.59–1.37)	0.95 (0.60–1.51)
Twice, 88 (11.9)	1.05 (0.59–1.84)	1.56 (0.83–2.94)	0.93 (0.50–1.72)	2.21* (1.23–3.94)
Several times every night, 99 (13.4)	1.07 (0.62–1.86)	1.74 (0.95–3.18)	1.02 (0.57–1.80)	1.79* (1.02–3.15)
Difficulty falling to sleep	**Music**		**Internet (social)**	
	Sometimes	Usually/always	Sometimes	Usually/always
Once, 188 (25.5)	1.04 (0.69–1.55)	1.54 (0.94–2.53)	0.81 (0.52–1.27)	0.87 (0.55–1.39)
Twice, 88 (11.9)	1.03 (0.58–1.82)	2.46* (1.34–4.53)	0.93 (0.49–1.71)	1.82* (1.03–3.21)
Several times every night, 99 (13.4)	1.17 (0.68–2.02)	2.85* (1.58–5.13)	0.94 (0.50–1.77)	2.59* (1.51–4.43)
Difficulty falling to sleep	**Video gaming**		**Computer or laptop (study)**	
	Sometimes	Usually/always	Sometimes	Usually/always
Once, 188 (25.5)	0.74 (0.47–1.16)	1.01 (0.59–1.73)	1.25 (0.84–1.88)	1.17 (0.68–2.01)
Twice, 88 (11.9)	1.31 (0.75–2.30)	1.53 (0.75–3.12)	1.65 (0.95–2.84)	2.09* (1.08–4.02)
Several times every night, 99 (13.4)	1.283 (0.71–2.16)	2.41* (1.26–4.59)	1.06 (0.62–1.80)	1.56 (0.82–2.96)
Night awakenings	**Television viewing**		**Internet (social)**	
	Sometimes	Usually/always	Sometimes	Usually/always
Once, 290 (39.3)	1.89* (1.27–2.79)	0.98 (0.62–1.56)	0.82 (0.54–1.23)	1.56* (1.03–2.36)
Twice or more, 98 (13.3)	1.26 (0.70–2.27)	1.59 (0.88–2.88)	0.78 (0.42–1.43)	1.66 (0.94–2.93)
Do not know, 52 (7.0)	1.77 (0.89–3.52)	0.99 (0.42–2.34)	0.63 (0.29–1.35)	0.86 (0.40–1.86)
Nightmares	**Television viewing**		**Video gaming**	
	Sometimes	Usually/always	Sometimes	Usually/always
Once, 174 (23.6)	1.23 (0.81–1.88)	1.01 (0.61–1.68)	0.90 (0.58–1.41)	1.22 (0.72–2.09)
Twice or more, 143 (19.4)	1.67* (1.06–2.65)	1.60 (0.95–2.71)	1.56 (0.99–2.47)	1.63 (0.92–2.88)
Nightmares	**Mobile telephones**		**Music**	
	Sometimes	Usually/always	Sometimes	Usually/always
Once, 174 (23.6)	0.78 (0.51–1.20)	0.59* (0.37–0.94)	0.80 (0.54–1.20)	0.78 (0.48–1.28)
Twice or more, 143 (19.4)	1.10 (0.68–1.77)	1.24 (0.76–2.00)	1.37 (0.86–2.17)	2.02* (1.22–3.45)

Data are presented as odds ratio (95% confidence interval), adjusted for gender, school, ethnicity, caffeine consumption, circadian preference, body mass index *z* score, lights on in room while sleeping, napping, and bedroom sharing.
Reference for technology and sleep parameters is never.
* $P < .05$.

Early evidence showed that insomnia patients spent significantly more time watching television compared to healthy sleepers [33]. Our data showed that frequent bedtime television viewers were more than four times more likely to report frequent early awakening episodes, a defining feature of insomnia. It is possible that those with insomnia watch television to utilize additional waking time. However, the reverse also may be plausible in that our data also showed that television viewing was associated with greater difficulty shutting off participants' minds before attempting sleep initiation, a common problem in those with insomnia. Artificial light emission from electronic devices has been shown to suppress melatonin, adversely affect sleep initiation [34,35], and alter sleep architecture [35]. Television content (fear) also may play a role in symptoms of insomnia or other sleep concerns, particularly in pediatric populations [36]. A combination of mental excitation and delayed melatonin release therefore may exacerbate the delayed circadian shift commonly experienced by adolescents.

Table 4
The odds ratios and 95% confidence intervals for logistic regressions between specific technologies and sleep parameters in 738 UK adolescents.

	Model 1	Model 2	Model 3
Difficulty turning off			
Television viewing			
Sometimes	1.23 (0.88–1.72)	1.28 (0.90–1.81)	1.23 (0.86–1.75)
Usually/always	1.99* (1.35–2.94)	2.11* (1.40–3.17)	1.93* (1.27–2.92)
Mobile telephone			
Sometimes	0.96 (0.68–1.36)	0.91 (0.64–1.30)	0.84 (0.58–1.20)
Usually/always	1.56* (1.09–2.23)	1.47* (1.02–2.11)	1.33 (0.91–1.93)
Computer or laptop (study)			
Sometimes	0.94 (0.67–1.30)	0.99 (0.70–1.39)	0.94 (0.67–1.33)
Usually/always	1.74* (1.15–2.63)	2.16* (1.40–3.34)	2.01* (1.29–3.13)
Internet (social)			
Sometimes	1.07 (0.74–1.55)	1.12 (0.77–1.63)	1.09 (0.75–1.59)
Usually/always	1.58* (1.11–2.24)	1.64* (1.15–2.35)	1.50* (1.04–2.16)
Video gaming			
Sometimes	1.32 (0.93–1.86)	1.45* (1.02–2.08)	1.38 (0.96–1.98)
Usually/always	1.43 (0.96–2.14)	1.84* (1.19–2.85)	1.76* (1.13–2.74)
Sleepwalking			
Television viewing			
Sometimes	2.16* (1.16–4.02)	2.19* (1.15–4.17)	2.30* (1.20–4.41)
Usually/always	3.67* (1.95–6.90)	3.59* (1.86–6.94)	3.70* (1.89–7.27)
Video gaming			
Sometimes	1.82* (1.03–3.23)	1.81 (1.00–3.25)	1.86* (1.02–3.38)
Usually/always	1.95* (1.03–3.71)	2.01 (1.00–4.04)	2.07* (1.02–4.20)
Computer or laptop (study)			
Sometimes	1.62 (0.92–2.84)	1.68 (0.95–2.98)	1.77 (0.99–3.16)
Usually/always	1.85 (0.95–3.59)	2.05* (1.03–4.09)	2.18* (1.07–4.42)

Data are presented as odds ratio (95% confidence interval).
Referent for technology type and sleep parameters is never.
Model 1: unadjusted.
Model 2: adjusted for gender, school, and ethnicity.
Model 3: further adjusted for caffeine consumption, circadian preference, body mass index *z* score, lights on in room while sleeping, bedroom sharing, and napping.
* $P < .05$.

The relationship between Internet overuse and daytime sleepiness has been explored in adolescents [37]. Internet overuse was characterized using a previously validated test and demonstrated that addicts were at greater risk for subjective insomnia. Our results parallel these findings demonstrating that frequent social networkers were three times more likely to report more frequent early awakening and two times more likely to report having twice weekly episodes compared to nonusers. A recent large-scale study [38] also reported that Internet use was a significant predictor of short sleep duration in adolescents. Recent data [39] also suggested that the adverse effects of Internet use on sleep were not restricted to adolescents but also may apply to adult populations.

Insomnia relates to difficulty initiating or maintaining sleep. Not only did our data show that frequent early awakening episodes were associated with frequent mobile use, we also observed that frequent mobile users were almost twice as likely to report frequent problems initiating sleep. Exposure to radio frequency from mobile telephones has been previously associated with altered sleep architecture, including lengthened stage 2 sleep and increased latency for slow-wave sleep [40], which may reflect the sleep architecture of diagnosed insomnia.

Thomée et al. [41] explored the association between sleep disturbances and a range of technologies in young adults. Gender differences were reported and demonstrated that regular Internet browsing in girls was associated with increased nocturnal awakening. Our findings support these results and although we did not explore gender differences, we did adjust for gender in our analyses. It is possible that acoustic alerts may contribute to waking individuals throughout the night if computers remain on during sleep.

4.3. Parasomnias

Nightmares in children may arise from genetic predisposition, trait anxiety, or traumatic experiences [42]. Few adolescent studies have investigated the relationship between nightmares and technology use; however, a recent review by Van den Bulck [43] showed that technology use may cause recurring nightmares and another study [37] found a positive association between nightmares and Internet use. We illustrated that frequent music listeners were twice as likely to experience nightmares on more than one occasion compared to nonviewers. More frequent reports of nightmares also were associated with frequent mobile telephone use, video gaming, and listening to music. It is possible that exposure to violent content (visual or verbal) before bedtime may promote adverse sleep outcomes such as nightmares. A recent review [44] highlighted that only two studies have previously explored the impact of music on adolescent sleep, but music was considered as a sleep aid and not an inhibitor in both cases. Our findings are important, as we showed that music was the greatest contributor to the occurrence of nightmares. Music content or genre may result in visual imagery which subsequently translates into adverse dreaming content resulting in nightmares. However, the precise mechanisms involved require comprehensive assessment.

Sleepwalking episodes can be triggered by sleep deprivation [45]. This statement has been verified by parental reports along with the suggestion that television content may trigger nightmares and sleepwalking [46]. Our findings suggest that television viewers were 2–3 times more likely to report sleepwalking than nonviewers. To our knowledge, there are no studies that have investigated the relationship between sleepwalking and other technologies in adolescents. We further report an association between sleepwalking and frequent video gaming and computer use. It is possible that watching television, playing video games, and using the computer may contribute to sleepwalking through negative effects on other sleep parameters (e.g., reduced sleep duration, prolonged sleep onset, early awakenings), though this hypothesis requires further investigation.

4.4. Strengths and limitations

To our knowledge, our study is the first to examine effects of specific types of technology on multiple sleep parameters in the same adolescent sample. The Midlands Adolescents Schools Sleep Education Study benefits from a large sample, allowing multiple assessments and adjustment for potential confounders. Although the study aim was to directly examine relationships between multiple sleep outcomes and weekday bedtime technology use while controlling for a range of potential confounders, future studies may consider examining mediating and moderating effects of these confounders in relation to adolescent sleep and technology use. Our study compliments and extends the current understanding of associations between specific technologies and multiple sleep parameters in early adolescence.

There are several limitations to acknowledge. All data collected were self-reported and may be subject to biases or inaccuracies; future studies may consider utilizing sleep diaries or actigraphy as an alternative method. Some sleep parameters were based on acute reports 2 weeks before providing information. This type of report may not provide an accurate representation but may have reduced recall inaccuracies or biases. Self-reported sleepwalking and nightmares may be subject to inaccuracies, as the former requires this information to be passed to the participant through a third party (i.e., parent, sibling) and the latter may be difficult to recall. Furthermore, sleep data that were obtained were unlikely to be a consequence of a sleep disorder, as those with diagnosed sleep disorders were excluded. However, we do acknowledge that there may have been a small number of participants with undiagnosed sleep disorders within our sample. Although we did adjust for a range of confounders, we did not collect information on daytime impairment or pubertal status. Further, although frequency of technology use before bedtime was obtained, we did not ascertain duration. We also acknowledge that our study cannot determine temporal sequences due to the cross-sectional study design, and thus warrants detailed prospective adolescent sleep-technology studies.

5. Conclusions

Engaging in weekday bedtime technology use may adversely effect the sleep of adolescents. Frequent bedtime technology use of any of the devices we investigated was associated with reduced sleep duration. Frequency of use rather than quantity of bedroom technology appears to be more harmful in this age group. Adolescents who listen to music at bedtime may be at greater risk for sleep problems. The link between parasomnias and bedtime technology use provides novel evidence. Future studies should explore potential interactions and pathways between bedtime technology, sleep loss, and parasomnias. Sleep parameters should be objectively measured to examine potential effects of technology on adolescent sleep. Electronic devices now serve multiple functions; therefore, comprehensive studies should assess the potential of electronic multitasking. Finally, prospective studies should be conducted to determine cause–effect relationships. In the meantime, interventions to educate preadolescents about technology use in parallel with promoting optimum sleep habits may reduce or prevent later sleep concerns in adolescents.

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Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2013.08.799.

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